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DEVELOPMENT A COST ESTIMATION METHODOLOGY FOR NORMALISED COMPONENTS OF COLD PLASTIC DEFORMATION EQUIPMENTS

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The cost estimation associated to components of cold plastic deformation equipments is facing with a number of complex influencing factors.

This study develops a methodology to estimate the cost/ purchasing price of the normalized components intended for use in cold plastic deformation equipments, using the regression analysis.

The methodology is exemplified based on a case study.

Keywords: cost estimation, normalized/ standard components, cold plastic deformation.

1. Introduction

Within an economic environment with a fierce competition, the cost/ purchasing price estimation activity must be a basic concern of any organization that manufactures specific products. Because the normalized components are purchased by other firms to integrate them into new products, their purchase price becomes costs component in the new developed product.

The cost control process can be broken down into four functions: cost estimation, monitoring, calculation and evaluation of manufacturing cost and cost modeling [1,2].

Two basic approaches for the cost estimation may be distinguished: *analytical method* – to generate a cost estimation and *analogical method* – to obtain a cost estimation based on variants. By combining these two approaches, a *hybrid method of estimating the cost* results [3].

The principle for generating a cost estimation is based on the formation of the components of product cost, while the estimate of costs based on variants used similar products manufactured in the past for determining costs [4, 5].

The difference in appliance between these two approaches is illustrated with the help of *the paradox of the cost estimation*, as presented in Fig. 1 [3]. It is required to make accurate cost estimates during design, since design fixes about 70% of the product costs. But how during the design process the product information is not yet available in full detail, it's difficult to make accurate

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estimates. In variant based estimation, more information is available at the beginning of the product development cycle than in the case of a cost estimate by generation.

A synthesis of the cost estimation methods, used in various stages of product development, is quoted in Fig. 2 [6].

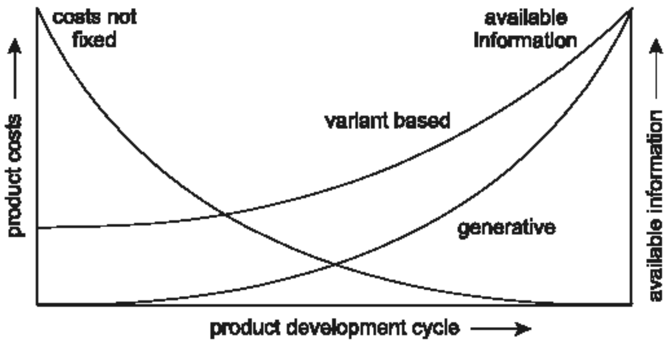

Fig. 1. The paradox of cost estimation through generation and based on variants [3]

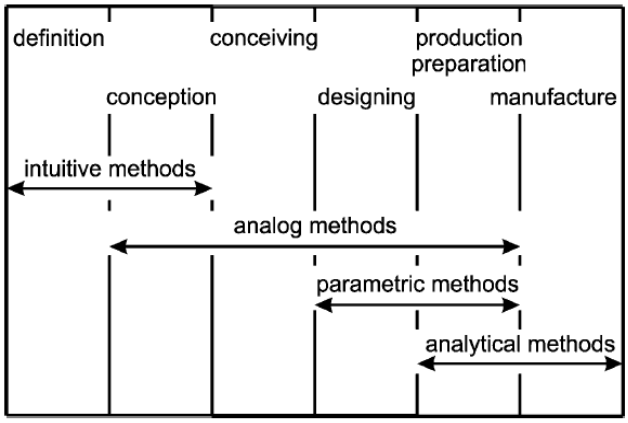

Fig. 2. Methods for cost estimation at different stages of product development [6]

Cost estimation methods could be characterized as follows: *intuitive methods* – cost estimation is based exclusively on the capabilities of an expert assessor; *analogical methods* - cost estimation is on the basis of similarity between certain products; *parametric methods* – the cost is evaluated on the basis of the product characteristics which are given in the form of parameters/ factors of influence; *analytical methods* – the cost is determined on the basis of the individual planned total costs [6].

Most of the literature take into consideration three different groups of basic estimation technique for cost estimation method classification (analogous estimation/ analogical techniques, parametric estimation/ parametric techniques and bottom-up estimation/ analytical techniques. The existing estimation models can either be directly associated with one of these three methods or can be seen as a conjunction of two or with all three basic models [7].

When trying to categorize the different existing cost estimating techniques one could, for example, use the extensive approach proposed in [8], shown in Fig 3.

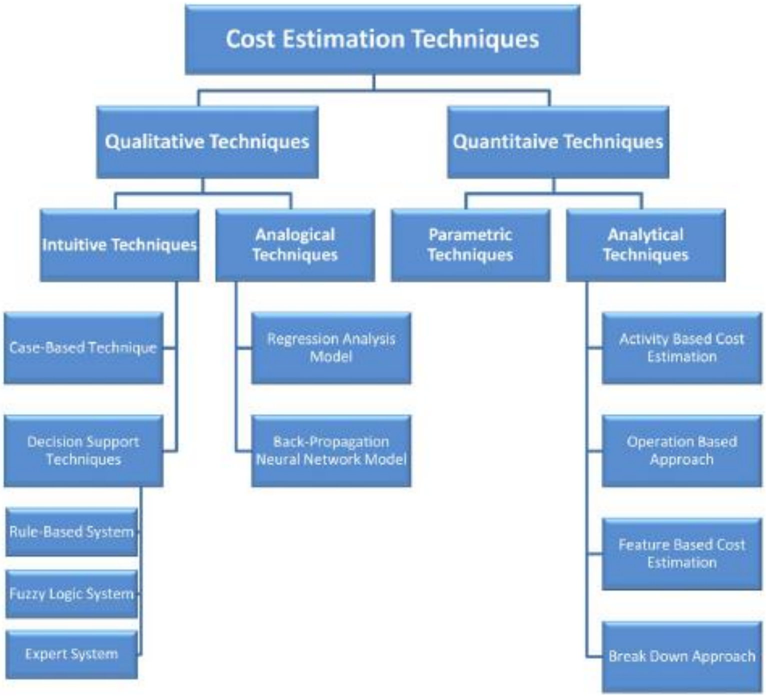

Fig. 3. Detailed classification of cost estimation techniques [8]

In analytical techniques, all work steps, with their costs for material, work, infrastructure, etc., are added up to produce the products final costs. For this kind of estimation or calculation deep understanding of the process, the process interactions and the part design details have to be available. The advantages of this method are the level of detail and the causation it is able to provide [9].

Information about the cost of future implementation of the new product is important. For this reason, it is urgent to indicate the appropriate cost estimating techniques. The hardest part is to assess the future costs at the planning stage. A large number of uncertain information makes the cost can be evaluated only subjectively [10].

Parametric estimation and regression analysis are widely used methods that respond best to the needs of efficient cost estimates in the early stages of product development process [11].

2. Development the structure of a cost estimation methodology

In production, the cost estimation is performed before any of the stages of product development cycle to be carried out.

To estimate the cost/ purchasing price of the normalized components from the structure of cold plastic deformation equipments, a methodology is proposed, "Methodology for Cost Estimation of Cold Plastic Deformation Equipments", MCE-CPDE.

Under MCE-CPDE, the cost estimation will be configured using the *parametric method*, and the regression analysis [12,13,14,15].

MCE-CPDE is structured as presented in Table 1.

Table 1

MCE-CPDE Structure

Stage	Stage description	Information providers
(1)	Analysis of the drawing or of the sketch of the part for which the cost-estimation is about to be done	- Equipment Designer - Price Lists and Catalogs
(2)	Obtaining information regarding the cost or price from historical data, *or* performing an experimental program using more constructive variables, changed on multiple levels, in order to determine the parts costs with an analytical method	- Price Lists and Catalogs - -Estimator
(3)	Proposing of an cost estimation function, where the cost represents the dependent variable, and a number of constructive parameters are independent variables	- Estimator
(4)	Selection of the significant variables within the proposed model	- Statistical analysis data software
(5)	Determination of the coefficients of the proposed model using the regression analysis	- Statistical analysis data software
(6)	Calculation of the estimated cost/ price and comparison with the analytical values obtained from the catalogues, thereby determining the estimation errors	- Estimator
(7)	Analysis of the estimation errors: - if *the errors are satisfactory*, it keeps the function obtained in step (5). - if *the errors are not satisfactory*, we go back to stage (3), introducing new terms into the model and re-stepping the process until the errors are satisfactory.	- -Estimator, *and/ or* - A decision-maker within the organization interested in estimation process

The regression analysis can be performed *simultaneously* or *in steps* using the program *NCSS 2007* [17].

The *simultaneous regression* assumes that the regression model is constructed by entering in the analysis, at the same time, all independent variables originally chosen.

The *stepwise regression* aims to reduce the initial set of variables to a smaller subset, but to express as much of the variation in the dependent variable; using this procedure, the independent variables are inserted or removed from the regression equation at any time. The stepwise regression may be performed in the following variants: through *inclusion*: the variables are introduced one at a time only if they meet certain specified criteria respecting the test *F* or *t*. The order in which they are placed is based on their contribution in explaining the variation of dependent variable; by *elimination:* at first, all the independent variables were included in the regression equation, after which they are removed one at a time, depending on the values of the test *F* or *t*; *combined estimation*: the inclusion of the variables is combined with the removal of those that no longer meet the criteria specified at every step.

The normalized elements can be found in the construction of differenf cold plasic deformation equipments, and their shape and sizes do not derive directly from the product to be obtained or from the associated technological scheme. The main such of normalized items are: basic and end plates, guide pillars, guide bushes, assembly elements (bolts, pins, clamps, keys) etc.

3. Case study

The present case study, as an exemplification of MCE-CPDE application, is referring to the determination of cost/ purchasing price of certain guide pillars intended for use in different cold plastic deformation equipments.

Stage (1): The relevant data of a guide pillar set [16] are as presented in Fig. 4 and Table 2.

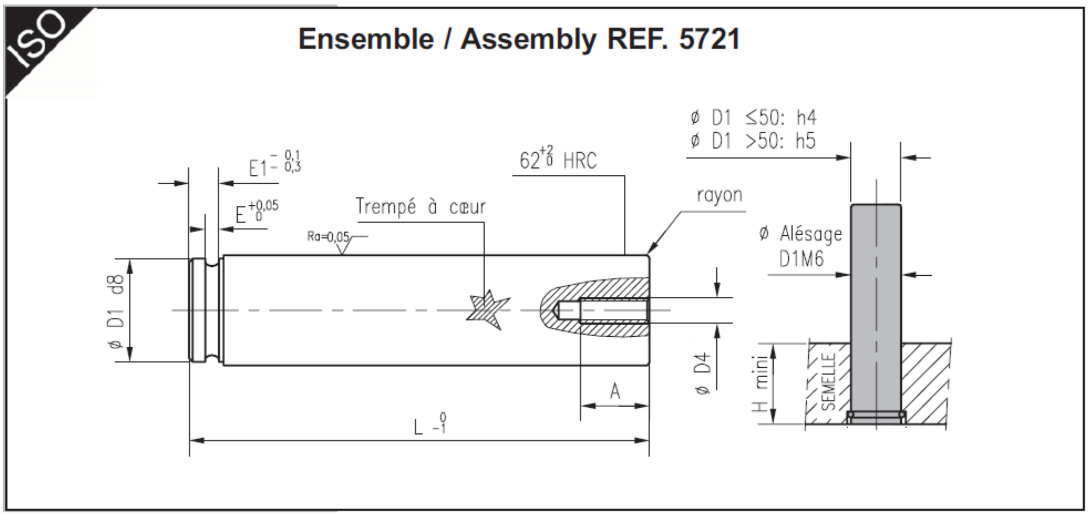

Fig. 4. Guide pillar, adapted in accordance with data from [16]

Table 2

Sizes (mm) associated to the guide pillar represented in Fig. 4 [16]

D L	12	16	20	25	32	40	50	63	80
100									
125									
140									
160									
180									
200									
224									
250									
280									
315									
355									
400									
450									
500									
A	-	-	10	12	16	16	16	27,5	36
D_4	-	-	M5	M6	M6	M10	M10	M10	M12
E_1	4	4	6	6	10	10	10	16	16
E	1,7	1,7	2,7	2,7	4,2	4,2	4,2	6,2	6,2

Stage (2): Let E be the *experimental* program, i.e., the set of *experimental* values associated to independent and dependent variables, necessary to determine P function, as presented by rel. (1).

$$E = \{(De_i, Le_i, Pe_i)_i \mid i = \overline{1, n}\} \quad (1)$$

E was designed based on the data defining the considered guide pillar set, i.e., De and Le - according to data from Table 2, and Pe – as function of (De, Le) from a specific commercial price list, in euros, n = 60, as presented by rel. (2). It was used an complete experimental program rather than a factorial program (see *Table 2* with available prices).

$$E = \{(12, 100, 10.99)_1, (12, 125, 12.88)_2, \ldots, (80, 500, 354.56)_{60}\} \quad (2)$$

Stage (3): To estimate the cost/ purchase price, P, of an item from the considered guide pillars set, there has been defined a function of polinomial type, with two independent variables, i.e., pillar diameter, D, and pillar length, L, and the interdependencies between them, up to grade 3, as presented by eq. (3). We used a polynomial estimation function because, for a limited range of variation, it reproduces with controllable accuracy experimental data. The two independent variables materializes workpiece volume (incorporating practical information related to material cost and processing time).

$$P = b_0 + b_1 D + b_2 L + b_3 D^2 + b_4 L^2 + b_5 DL + b_6 D^2 L + b_7 DL^2 \tag{3}$$

Stage (4): Running the stepwise regression through the *inclusion*, on the *P* function defined by eq. (3), revealed the significant terms as being only b_0, $b_1 D$, $b_6 D^2 L$. Thus, the adopted P function is as presented by eq. (4).

$$P = a_0 + a_1 D + a_2 D^2 L \tag{4}$$

Stage (5): Further, *NCSS 2007* was applied for the E experimental program defined by rel. (1) and (2). The main results are the regression coefficients a_0, a_1, a_2 of the P function and the correlation coefficient R^2 as presented by rel. (5).

$$a_0 = 13.1771,\ a_1 = -\ 0.2324405,\ a_2 = 1.017555 * 10^{-4},\ \ R^2 = 0.996 \tag{5}$$

Stage (6): Let Pc be the value of the P cost/ purchasing price determined by *calculus*, i.e., by applying the eq. (4).

Thus, e.g., the values of Pc_i, in euros, corresponding to the Pe_i values from the rel. (2) are: 11.85, 12.22, …, 320.2, the total number of these being n, n = 60.

An overall illustration of the main data concerning the above D, L, Pe, Pc is as presented in Fig. 5.

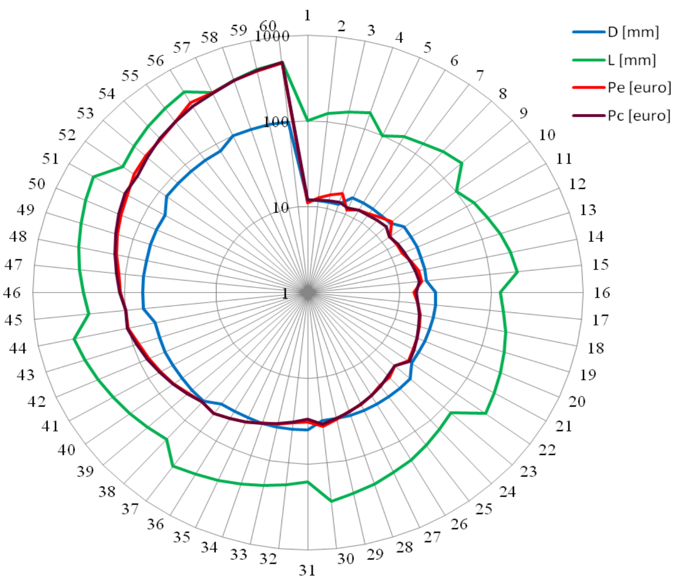

Fig. 5. Radar chart refferring to the values of D, L, Pe, Pc, on logarithmic scale, for each i, i: 1, 2, ..., 60

The relative error ε = 100(Pc – Pe)/Pe, in %, represents an indicator of the accuracy associated to the P function.

Stage (7): Among the set of n = 60 values of ε, the extreme values being – 22.03% and + 8.29%, intervals with length of max. 5% are considered as presented in Fig. 6, and each value of ε is placed in a proper interval. The result is as follows (Fig. 6):

- υ = 39, i.e., 65% of ε values belong to interval (-5%, 0) or (0, +5%);
- υ = 17, i.e., 28% of ε values belong to interval (-10%, -5%) or (5%, 9%);
- υ = 4, i.e., 7% of ε values belong to the interval (-23%, -10%).

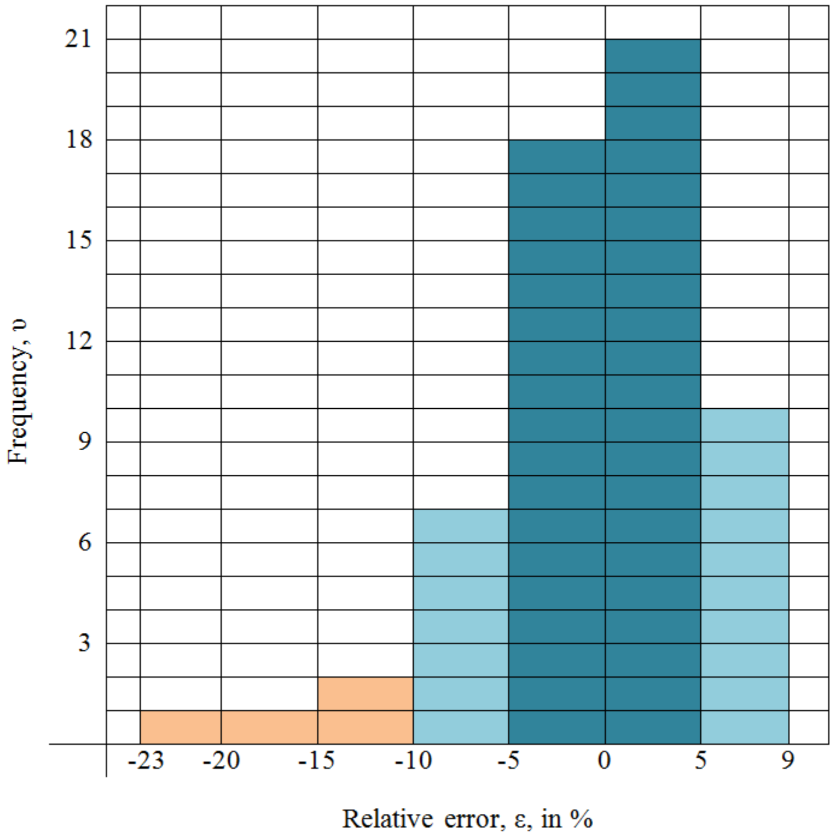

Fig. 6. Distribution of relative error

The value of the regression coefficient R^2, i.e., R^2 = 0.996, as well the distribution of the relative error ε reveal a satisfactory accuracy of the P function defined by rel. (4) and (5).

4. Conclusions

The cost estimation associated to components of cold plastic deformation equipments is a complex problem, which requires continuous interests to develop increasingly efficient tools for cost analysis in an early stage of the design process.

The methodology developed by the present work, based on regression analysis, allows to determine analytical functions for estimation accurately and quickly the cost/ purchasing price of normalized components intended for use in different cold plastic deformation equipments, in their conceptual design phase.

The average error estimate for the analyzed normalized component is of -0.79 %, which demonstrates the usefulness of the estimation methodology developed under this work.

The conducted study, by the original contributions, constitutes a useful guide for the realization of the price catalogues by the producing companies, and also to the customers who wish to obtain a right price quotation in the process of negotiating with the supplier companies, where the product requested is not part of the standard product range delivered by supplier.

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